(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 October 2001 (25.10.2001)

PCT

(10) International Publication Number
WO 01/79012 A2

(51) International Patent Classification[7]: B60K 6/00, B66F 9/06, B60K 1/04, 5/10, B60L 11/12, H01M 16/00

(21) International Application Number: PCT/US01/12148

(22) International Filing Date: 13 April 2001 (13.04.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/197,391 14 April 2000 (14.04.2000) US

(63) Related by continuation (CON) or continuation-in-part (CIP) to earlier application:
US 60/197,391 (CIP)
Filed on 14 April 2000 (14.04.2000)

(71) Applicant *(for all designated States except US)*: **AIR-TRAX CORPORATION** [US/US]; P.O Box 1237, Hammonton, NJ 08037-1237 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **HARRIS, Donald, B.** [US/US]; 2624 South Ives Street, Arlington, VA 22202 (US). **AMICO, Peter** [US/US]; 870-B Central Avenue, Hammonton, NJ 08037 (US).

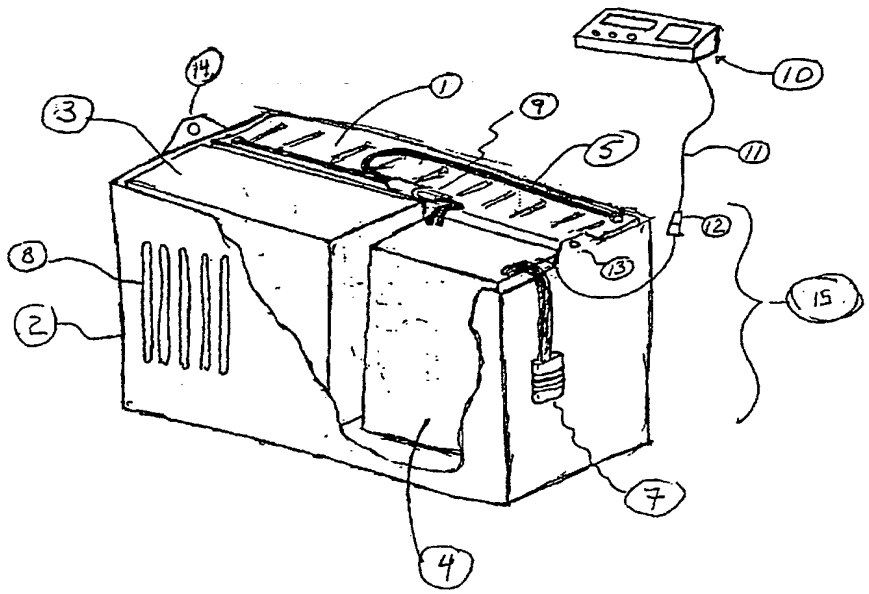
(74) Agents: **LAW, Glenn** et al.; Foley & Lardner, Suite 500, 3000 K Street, N.W., Washington, DC 20007-5109 (US).

(81) Designated States *(national)*: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CO, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: HYBRID POWER SUPPLY MODULE



(57) Abstract: An hybrid power supply module is disclosed. The hybrid power supply module is configured for placement in a battery compartment of an electrically powered machine and includes a housing that contains a battery, an electrical generator or fuel cell, and control electronics. The housing is sized to fit in the host electrically-powered machine's battery compartment. The battery and electrical power generator or fuel cell are coupled electrically to the electronic controls. A method of replacing a battery in an electric powered machine with a renewable power source is also disclosed. The method includes uncoupling the battery from the machine, removing the battery from a battery compartment of the machine, placing the hybrid power supply module in the battery compartment, and coupling the hybrid power supply module to the machine.

WO 01/79012 A2

TITLE OF THE INVENTION: Hybrid Power Supply Module

CROSS-REFERENCE TO RELATED APPLICATIONS: U.S. Application number: 09/056,109, filed 04/06/98. This application claims the benefit of priority from U.S. Provisional Application No. 60/197,391 filed April 14, 2000, which is hereby incorporated by reference.

STATEMENT OF GOVERNMENT INTEREST: Not applicable.

BACKGROUND OF THE INVENTION

[0001] The present invention relates generally to power supplies and, more particularly, to a hybrid removable power supply module for a machine such as a forklift, a car, a truck or any motorized vehicle or other machines requiring a power source.

[0002] Powered machinery, and particularly mobile machinery such as motorized vehicles, fork lifts, cars, trucks and vehicles using a regenerableable source of energy are generally designed to operate on either battery (e.g. rechargeable batteries) or fossil fuel power sources (e.g. internal combustion engine, turbine engine or fuel cell). While battery and fossil fuel powered mobile machinery may have quite similar chassis, suspension, lift equipment and hydraulics, the drive portions of the machinery are generally designed specifically for either a battery or fossil fuel power supply. The nature of the drive system design makes electric and fossil fuel machinery fundamentally different and not interchangeable. For example, a forklift design optimized for battery power might include a chassis having an electric motor that powers drive wheels, and an additional electric motor that drives a hydraulic actuation system to power on board auxiliary systems such as lifting, tilting and gripping mechanisms. Whereas, a forklift design optimized for fossil fuel power might incorporate an internal combustion engine that supplies rotary mechanical power to a single hydraulic system from which pressurized fluid is metered through operator controlled valves to hydraulic cylinders and motors which actuate lifting, tilting and gripping mechanisms and also drive the wheels. This optimization of vehicle system designs around the power source makes converting

installed in the vehicle, and directly supplies rotary mechanical power to the vehicle's drive train. The internal combustion engine output is also arranged to recharge the batteries, which are carried in a removable cassette under the vehicle. The battery cassette may be removed and the vehicle operated on power from the internal combustion engine alone.

[0007] U.S. Patent No. 4,320,814 to Middlehoven discloses a removable modular electro-hydraulic power source for mining machinery. This invention purports to provide the ability to rapidly replace the electric motor prime mover, reduction gear set, and hydraulic pumps, thus reducing vehicle down time for maintenance. The removed module is then refurbished in a facility better suited to such work than the mine. The power source for the disclosed system relies on externally provided electrical energy, supplied to the power source via an umbilical from a source remote from the mining machinery.

[0008] U.S. Patent No. 5,419,131 Doppstadt describes a displaceably mounted power unit for use in a mobile waste processing machine. This power unit is captured to the host machine on a hinged mount arranged to provide access to the machine's interior for maintenance and repair.

[0009] Concepts for removable power supplies described above either do not permit a change over from one energy source to another, or require additional structure and mechanisms necessary for both energy sources. Removable power supplies which do not permit switching between electrochemical and fossil fuel energy sources necessarily limit the vehicle applications as discussed above. Vehicles that require structure for both electrochemical and fossil fuel energy sources will necessarily be heavier, more costly and less reliable. Also, energy module designs that require special structural and mechanical interfaces with the vehicle necessarily mean that converting a host vehicle from one type of power source to the other will require expensive, time-consuming and complex modifications. These shortcomings have added to the cost of converting vehicles to hybrid-power sources, thus contributing to the limited commercial successes of hybrid-powered vehicles and hybrid-power conversions of existing vehicles.

[0010] Thus, there is a need for a power supply module that will enable a vehicle to be selectively operated on either battery or fossil fuel power without requiring additional

are permissible, while retaining the ability to function on battery power alone in areas where acoustic, thermal, and gaseous emissions are not desired.

[0015] By being interchangeable with a conventional battery, this invention permits the vehicle to be converted back to all battery power when fossil fuel capabilities are not useful, thus providing the ability to inexpensively increase the machine endurance.

[0016] Another objective of this invention is to provide a means by which a machine such as a forklift can be rapidly reconfigured between conventional battery only and combined battery and fuel cell or internal combustion engine power.

[0017] Yet another objective of this patent is to provide a hybrid power supply module consisting of a fossil fueled internal combustion engine powered generator or a fuel cell generator capable of supplying the average energy needs of an industrial machine, such as a fork lift, mated with a battery which, together with the generator, are capable of satisfying peak power requirements, along with the systems to modulate and control state and rate of charge, peak currents, and over running load power regeneration, all packaged in a volume and weight equal to or less than that of the battery that it replaces.

[0018] Another objective of this invention is to provide an energy module that can enable on-the-fly change over of power supply so that a fork lift or other mobile machine can operate without pollution in a factory wherein workers are employed and revert back to a warehouse using internal combustion provided power without stopping to make physical changes to the vehicle.

[0019] Accordingly, the present invention provides solutions to the shortcomings of prior power sources. Those of ordinary skill in the art will readily appreciate, however, that those and other details, features and advantages will become further apparent as the following detailed description of the preferred embodiments proceeds.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. 1. is a cut away perspective view of the first preferred embodiment of the invention showing components and their general arrangement;

[0027] The hybrid power supply module 15 housing 2 may be fabricated from, for example, metal, plastic, or another suitable material and may be sized to fit into the battery compartment of an electric powered mobile machine such as a fork lift or other mobile equipment. The housing 2 of FIG. 1, may also have a smooth exterior surface and lack protrusions from the exterior surface to simplify installation into and removal from battery compartment. The housing 2 is equipped with first lift point 13 and second lift point 14 to facilitate handling by overhead hoist machinery. Ports for exterior air intake and exhaust discharge 8 may be provided and are depicted on the side of the module in FIG. 1. The air intake and exhaust discharge ports 8 may alternately be located on any side, top, or bottom of the housing 2.

[0028] The fuel cell fuel storage container is depicted as being integral with the fuel cell 3 and thus may be incorporated into the housing 2 as shown in FIG. 1, to form a single, self-contained hybrid power supply module 15 that can be lifted, transported, stored, installed, operated, and removed from the host machine as a single unit. In another embodiment, the fuel storage tank not shown is carried by the host vehicle external to the hybrid power supply module 15. The fuel supply tank, not shown, will have a pipe connection, not shown, to convey fuel to the fuel cell 3, and may have a fill connection, not shown, to replenish fuel, and a means to sense and transmit fuel level to the control electronics 4, not shown.

[0029] The fuel cell 3 may be a common type that oxidizes hydrogen or other fuel and produces an electrical current. The fuel cell 3 will be electrically connected to the control electronics 4. The control electronics 4 will monitor all facets of the hybrid power supply module 15 including the fuel cell's 3 temperature and other operating parameters, fuel supply level, electrical currents, and battery 1 voltage.

[0030] The first preferred embodiment of the invention is presented schematically in FIG. 2. Referring now to FIG. 2, as shown in the schematic, solid lines depict the flow of power whereas dashed lines depict the flow of information. The battery 1, electronic controls 4, and host vehicle 31 power input 7 are electrically connected in parallel on a single buss 16. The control electronics 4 will condition the electrical energy from the fuel cell generator 3 and supply current to the buss 16. The electronic controls 4 are arranged to continuously and

this translates to 48 v- [0.2 v/cell][24 cells] or 43.2 volts for a fully charged battery 26 or 42 v - [0.2 v/cell][24 cells] or 37.2 volts when fully discharged.

[0036] A lead acid battery is recharged by reversing the flow of electric current. Electricity flows from higher potential to a lower one, so for electrical current to flow into the battery its potential must exceed that of the battery 1. Charging potentials for lead acid batteries are typically about 0.3 volts per cell, or so, above the battery's 1 open circuit potential which will result in an electrical current roughly equivalent to 15 percent of the "six hour rate" ampere-hour rating. Greater potentials and currents are not desirable, since these may damage the battery 1. Furthermore, as the battery 1 is charged the current must be reduced so the battery 1 does not overheat.

[0037] When the battery 1 is at a low charge, or current draws by the host vehicle 31 is high, as indicated by a low electrical buss 16 potential, the fuel cell 3 and electronic controls 4 will supply a higher current to the buss 16. When there is little current drawn by the host vehicle 31 and the battery 1 is nearly fully charged, as indicated by a high electrical buss 16 potential, the fuel cell 3 and electronic controls 4 will supply a smaller current to the buss 16. The fuel cell 3 and electronic controls 4 will reduce the current to the battery 1 to a very small value when it reaches a value which corresponds to a fully charged battery 1. In one preferred embodiment of the invention, the fuel cell 3 and electronic controls 4 are arranged to provide maximum current at buss potentials below about 1.75 volts per cell, current in amperes of approximately 15 percent of the battery 1 "six hour rate" ampere-hour rating at buss 16 potentials from 1.75 to 2.1 volts per cell, current of about 4 percent of the battery 1 "six hour rate" ampere-hour rating at buss 16 potentials from 2.1 to 2.7 volts per cell, and current not exceeding 0.5 percent of the battery 1 six hour ampere-hour rating at buss 16 potentials above 2.7 volts per cell. When static or operating at low loads, the electrical current supplied to the buss 16 from the fuel cell 3 via electronic controls 4 serves to maintain the battery 1 in a state of high charge and to prevent damage from overcharging. This translates to the following for the aforementioned illustrative example:

shown) for conveying the measured parameters. In one embodiment, a switch (not shown) is provided on the operator display and interface 10 for the operator to select manual or automatic fuel cell 3 operation. Push buttons (not shown) are provided on the operator display and interface 10 for starting and securing the fuel cell 3 when in the manual mode.

[0040] The hybrid power supply module 15 may have two modes of operation: manual and automatic. In the manual mode, the authority to operate the fuel cell 3 resides with the operator. The operator may, for example, start the fuel cell 3 to replenish the battery 1 charge by depressing the start button (not shown) on the operator display and interface 10. The fuel cell 3 will then start and supply electrical current to the buss 16 via controls 4 without further action by the operator. Depressing the stop button (not shown) will secure the fuel cell 3. The electronic controls 4 may also function to shut-off the fuel cell 3 automatically if the battery 1 becomes 100% charged to prevent damage to the battery 1 from overcharging. The manual mode is generally selected to prevent operation of the fuel cell 3 when operating in areas where waste heat, moisture, and fumes are problematic. The automatic mode is generally used when functioning in areas where the waste heat, moisture, and fumes from the fuel cell 3 are acceptable. In all cases, the electronic controls 4 will inform the operator of the state of charge of the battery 1 and advise when the fuel cell 3 should be operated to replenish the battery 1 when discharged. In the automatic mode, the electronic controls 4 will automatically start, operate, and secure the fuel cell 3 in accordance with predetermined values of sensed parameters including battery charge level and host vehicle energy consumption rate.

[0041] Whether in manual or automatic mode, the function of the fuel cell 3 is overseen by the electronic controls 4 which starts, operates, monitors, and secures the fuel cell 3 without further action by the operator. The electronic controls 4 monitor the fuel cell 3 performance parameters such as temperature, fuel level, and electrical status, and convey visual and audible alerts, cautions, and warnings to the operator via the operator interface and display 10 when values outside a prescribed range are sensed. The fuel cell 3 may be arranged to automatically reduce output or secure if a critical sensed parameter such as temperature reaches a predetermined threshold. In that event, the operator will also be notified via visual and audible alerts of the termination along with the condition that caused the shut-down.

engine. For example, a suitable internal combustion engine would Fischer Panda PMS 04 D, which produces 4 Kilowatts of electrical power using diesel fuel and is contained within an envelope of 21 inch high, 21 inches long, and 15 inches wide including starting, cooling, muffling, and engine control systems. The internal combustion engine 21 will be fitted with ancillary starting, intake air filtration, cooling, lubricating, muffling, and speed governing systems well known to those practiced in the art and not shown in any FIG. All such ancillary equipment and systems are contained within the housing 25. The internal combustion engine 21 will be fitted with sensors not shown which provide an electrical signal which can be correlated to the engine 21 temperature and lubricating oil pressure. These sensed parameters will be transmitted to the electrical controls 24 via electrical cabling not shown.

[0045] The fuel storage tank 23 may be incorporated into the housing 25 as depicted in FIG. 3, to form a single, self-contained hybrid power supply module 20 that can be lifted, transported, stored, installed, operated, and removed from the host machine as a single unit. In another embodiment, the fuel storage tank 23 is carried by the host vehicle external to the hybrid power supply module 20. The fuel supply tank will have a pipe connection not shown to convey fuel to the internal combustion engine 21, a fill connection not shown to replenish fuel, and a means to sense and transmit fuel level to the control electronics 24, also not shown.

[0046] The generator 22 may be a common type that converts mechanical energy, in the form of, for example, a rotating shaft of the internal combustion engine 21, to electrical energy. The generator 22 will be electrically connected to the control electronics 24. The control electronics will monitor all facets of the hybrid power supply module 20 including the internal combustion engine's 21 speed, temperature, and lubricating oil pressure, fuel tank 23 level, electrical currents, and battery 26 voltage / state of charge.

[0047] The second preferred embodiment of the invention is presented schematically in FIG. 4. As shown in the schematic, solid lines depict the flow of power whereas dashed lines depict the flow of information such as commands and sensed parameter feedback. Referring now to FIG. 4, the battery 26 , electronic controls 24, and host vehicle 31 power input 27 are electrically connected in parallel on a single buss 17. The control electronics 24 will rectify and condition the electrical energy from the generator 22 and supply current to the buss 17.

controls 24 will supply a higher current to the buss 17. When there is little current drawn by the host vehicle 31 and the battery 26 is nearly fully charged, as indicated by a high electrical buss 17 potential, the generator 22 and electronic controls 24 will supply a smaller current to the buss 17. The generator 22 and electronic controls 24 will reduce the current to the battery 26 to a very small value when it reaches a value which corresponds to a fully charged battery 26. In one preferred embodiment of the invention, the generator 22 and electronic controls 24 are arranged to provide maximum current at buss potentials below about 1.75 volts per cell, current in amperes of approximately 15 percent of the battery 26 six hour ampere-hour rating at buss 17 potentials from 1.75 to 2.1 volts per cell, current of about 4 percent of the battery 26 six hour ampere-hour rating at buss 17 potentials from 2.1 to 2.7 volts per cell, and current not exceeding 0.5 percent of the battery 26 six hour ampere-hour rating at buss 17 potentials above 2.7 volts per cell. When static or operating at low loads, the electrical current supplied to the buss 17 from the generator 22 and electronic controls 24 serves to maintain the battery 26 in a state of high charge and to prevent damage from overcharging. This translates to the following for the illustrative example:

Buss Potential, Volts	Current Supplied to Buss by Generator and Electronic Controls, Amperes
Below 42	70
42 to 50.4	25
50.4 to 64.8	7
Above 64.9	1

[0052] The electrical power generator 22 may not be capable of supplying the transient peak energy demands of the forklift 31 or other host vehicle. This will manifest itself when more electrical current is drawn from the buss 17 than can be supplied by the generator 22 via the electronic controls 24. In this instance, the excess power required is supplied by the battery 26. This occurs when the host vehicle's 31 electrical current demand exceeds the maximum value of electrical current available from the generator 22 and electronic controls 24. In this case, the current from the generator 22 via the control electronics 24 which normally charges the battery 26 reverses to make up the difference. This reversal occurs automatically and passively. After the transient event has passed, and the host vehicle 31 electrical current

[0055] The manual mode is generally selected to prevent operation of the power internal combustion engine 21 when functioning in areas where noise, heat, and fumes are problematic. The automatic mode is generally used when functioning in areas where the noise, heat, and fumes from the internal combustion engine 21 are acceptable. In all cases, the operator display and interface 28 will inform the operator of the state of charge of the battery 26 and advise when the generator 22 should be operated.

[0056] Whether under manual or automatic control, the function of the generator is overseen by the electronic controls 24 which starts, operates, and monitors, and secures the generator without action by the operator beyond pressing the appropriate button.

[0057] The electronic controls 24 monitor the internal combustion engine 22 performance parameters such as temperature, oil pressure, fuel level, and electrical status, and conveys visual and audible warnings to the operator via the operator interface and display 28 when values outside a prescribed range are sensed. The internal combustion engine 21 and electrical generator 22 are shut down and secured automatically if a critical sensed parameter such as oil pressure or temperature reaches a predetermined threshold. In that event, the operator will also be notified via visual and audible alerts of the termination along with the condition that caused the shut-down.

[0058] Referring now to FIG. 5, the hybrid power supply module 20 is shown being lowered into an electric fork lift 33 battery compartment 34 wherein an access cover 35 of the forklift 33 is opened to receive the hybrid power supply module 20. While the second preferred embodiment of the hybrid power supply module 20 has been used to illustrate the act of installing it in the place of the regular electric fork lift 33 battery not shown. The installation of the first embodiment of the hybrid power supply module will be similar. The hybrid power supply module 20 may be placed in the forklift 33 by some means of an overhead lifting device not shown. It is also shown that the invention may be equipped with lifting fixtures 36 and associated hardware to facilitate handling by an overhead lifting device not shown. The forklift 33 illustrated includes an electrically powered drive train consisting of omni directional wheels 37 that are rotatably attached to the fork lift 33 chassis. A lifting mechanism 38 is also operably affixed to the fork lift 33 which may, for example, include lifting, tilting and gripping mechanisms to facilitate material handling by the fork lift 33. As

CLAIMS

What is claimed is:

1. A removable power source, comprising:

a housing ;

a battery disposed within said housing;

an electrical power generator disposed within said housing; and

a power control module disposed within said housing and coupled to said battery and said electrical power generator and arranged to supply power to a machine from either said battery or said generator.

2. The power source of claim 1, wherein said electrical power generator further comprises:

an internal combustion engine; and

an electrical generator coupled to said internal combustion engine.

3. The power source of claim 1, wherein said electrical power generator further comprises a fuel cell.

4. The power source of claim 1, wherein said housing is sized to fit in a compartment for holding a battery of said machine.

5. The power source of claim 4, wherein said housing is removable from the compartment for holding a battery.

6. The power source of claim 2, wherein said internal combustion engine is a spark ignition engine.

7. The power source of claim 2, wherein said internal combustion engine is a compression ignition engine.

8. The power source of claim 2, wherein said internal combustion engine is a rotary engine.

14. The vehicle disclosed in claim 12 wherein said vehicle is a work platform further comprising a scissor type lifting mechanism coupled to said chassis.

15. The vehicle of claim 12, wherein said housing is removable as a unit.

16. The power source of claim 1, wherein said electrical power generator further comprises:

an external combustion engine; and

an electrical generator coupled to said external combustion engine.

17. The power source of claim 16, wherein said external combustion engine is a gas turbine.

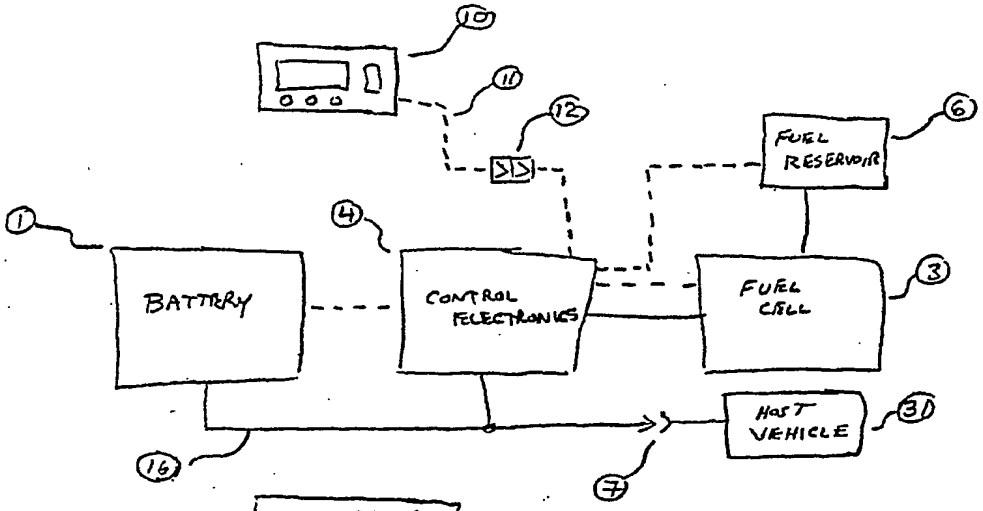


FIGURE 2

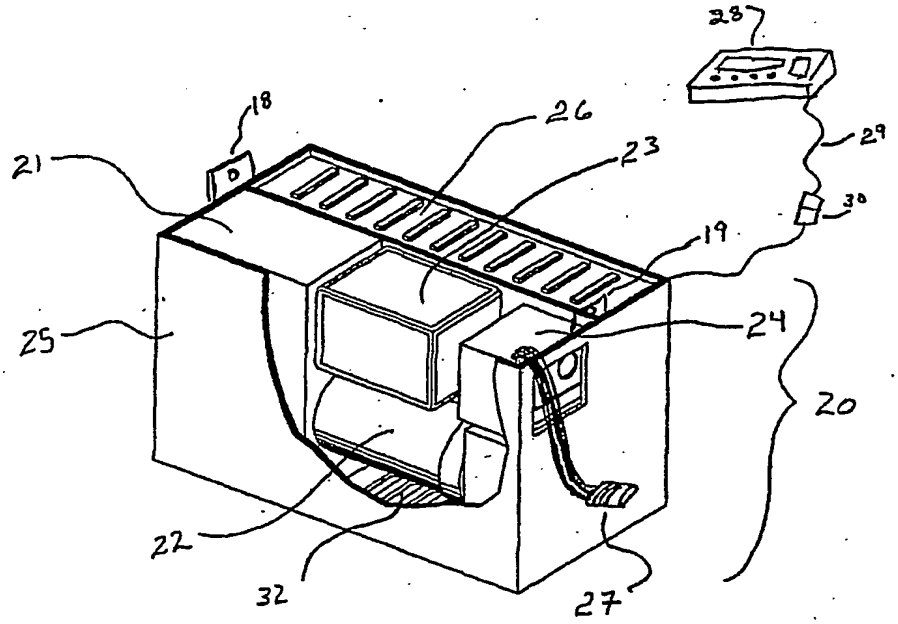


FIGURE 3

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 October 2001 (25.10.2001)

PCT

(10) International Publication Number
WO 01/79012 A3

(51) International Patent Classification[7]: B60K 6/00, B66F 9/06, B60K 1/04, 5/10, B60L 11/12, H01M 16/00, B60L 11/18, B60S 5/06

(21) International Application Number: PCT/US01/12148

(22) International Filing Date: 13 April 2001 (13.04.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/197,391 14 April 2000 (14.04.2000) US

(63) Related by continuation (CON) or continuation-in-part (CIP) to earlier application:
US 60/197,391 (CIP)
Filed on 14 April 2000 (14.04.2000)

(71) Applicant *(for all designated States except US)*: **AIR-TRAX CORPORATION** [US/US]; P.O Box 1237, Hammonton, NJ 08037-1237 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **HARRIS, Donald, B.** [US/US]; 2624 South Ives Street, Arlington, VA 22202 (US). **AMICO, Peter** [US/US]; 870-B Central Avenue, Hammonton, NJ 08037 (US).

(74) Agents: **LAW, Glenn** et al.; Foley & Lardner, Suite 500, 3000 K Street, N.W., Washington, DC 20007-5109 (US).

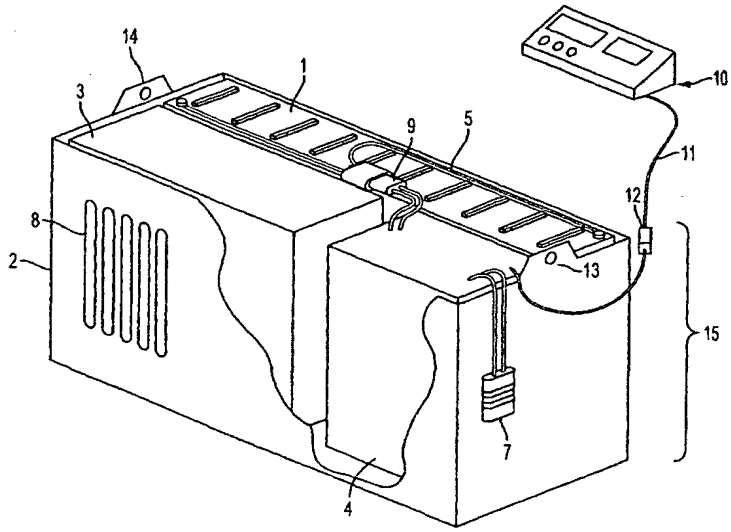
(81) Designated States *(national)*: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CO, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

[Continued on next page]

(54) Title: HYBRID POWER SUPPLY MODULE WITH INTERNAL COMBUSTION ENGINE OR FUEL CELL



(57) Abstract: An hybrid power supply module is disclosed. The hybrid power supply module is configured for placement in a battery compartment of an electrically powered machine and includes a housing that contains a battery, an electrical generator or fuel cell, and control electronics. The housing is sized to fit in the host electrically-powered machine's battery compartment. The battery and electrical power generator or fuel cell are coupled electrically to the electronic controls. A method of replacing a battery in an electric powered machine with a renewable power source is also disclosed. The method includes uncoupling the battery from the machine, removing the battery from a battery compartment of the machine, placing the hybrid power supply module in the battery compartment, and coupling the hybrid power supply module to the machine.

WO 01/79012 A3

'TERNATIONAL SEARCH REPORT

.national Application No
PCT/US 01/12148

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B60K6/00 B66F9/06 B60K1/04 B60K5/10 B60L11/12
H01M16/00 B60L11/18 B60S5/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B60K B60L H01M B66F B60S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 196 41 254 A (DAIMLER BENZ AG) 16 April 1998 (1998-04-16) * See ref. no. 20 - batteries contained in housing * column 4, line 13 - line 30; figures 3,5 ---	1,2,6, 9-12,15
X	US 4 339 015 A (FOWKES RONALD ET AL) 13 July 1982 (1982-07-13) claims ---	1,2,4-6, 9,12,15
X	US 3 497 027 A (WILD ALBERT F) 24 February 1970 (1970-02-24) column 9, line 52 - line 74; figures 1,2,6 ---	1-3,12, 15-17
X	WO 96 06749 A (EMME QUATTRO SRL ;MORI GIOVANNI (IT)) 7 March 1996 (1996-03-07) claims 1,8,13,14,25 --- -/--	1,2,6,7

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 October 2001	16/10/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Bufacchi, B

1

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

national Application No
PCT/US 01/12148

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 19641254 A	16-04-1998	DE 19641254 A1	16-04-1998
US 4339015 A	13-07-1982	BR 7906639 A	26-02-1980
		DE 2963519 D1	07-10-1982
		EP 0003888 A1	05-09-1979
		EP 0009027 A1	19-03-1980
		WO 7900630 A1	06-09-1979
		JP 55500080 T	14-02-1980
US 3497027 A	24-02-1970	NONE	
WO 9606749 A	07-03-1996	IT BS940094 A1	29-02-1996
		IT BS940095 A1	29-02-1996
		IT BS940096 A1	29-02-1996
		IT BS940097 A1	29-02-1996
		AU 3085695 A	22-03-1996
		WO 9606749 A1	07-03-1996
WO 9902358 A	21-01-1999	DE 19756083 A1	04-02-1999
		WO 9902358 A1	21-01-1999
		EP 0993385 A1	19-04-2000
US 4593786 A	10-06-1986	NONE	
DE 4321768 A	12-01-1995	DE 4321768 A1	12-01-1995
GB 1129709 A	09-10-1968	NONE	
EP 0936178 A	18-08-1999	JP 11222390 A	17-08-1999
		CN 1225333 A	11-08-1999
		EP 0936178 A1	18-08-1999
		US 6189636 B1	20-02-2001

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

CORRECTED VERSION

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 October 2001 (25.10.2001)

PCT

(10) International Publication Number
WO 01/079012 A3

(51) International Patent Classification[7]: B60K 6/00, B66F 9/06, B60K 1/04, 5/10, B60L 11/12, H01M 16/00, B60L 11/18, B60S 5/06

(21) International Application Number: PCT/US01/12148

(22) International Filing Date: 13 April 2001 (13.04.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/197,391 14 April 2000 (14.04.2000) US

(63) Related by continuation (CON) or continuation-in-part (CIP) to earlier application:
US 60/197,391 (CIP)
Filed on 14 April 2000 (14.04.2000)

(71) Applicant *(for all designated States except US)*: **AIR-TRAX CORPORATION** [US/US]; P.O Box 1237, Hammonton, NJ 08037-1237 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **HARRIS, Donald, B.** [US/US]; 2624 South Ives Street, Arlington, VA 22202 (US). **AMICO, Peter** [US/US]; 870-B Central Avenue, Hammonton, NJ 08037 (US).

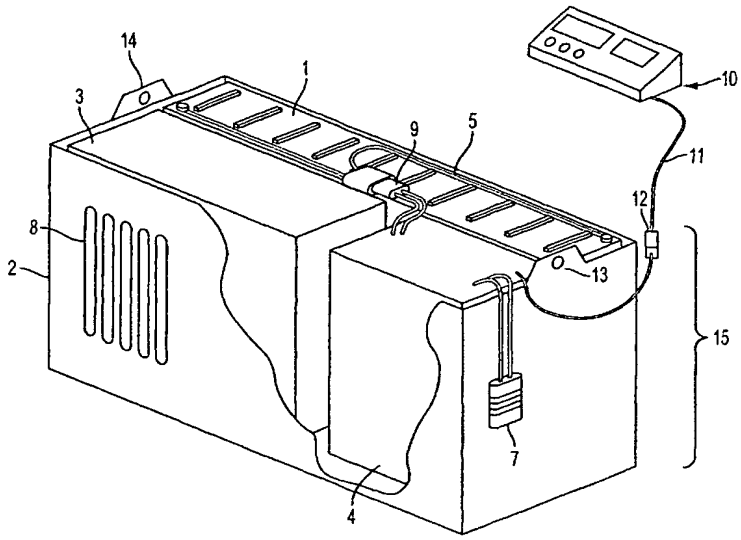
(74) Agents: **LAW, Glenn** et al.; Foley & Lardner, Suite 500, 3000 K Street, N.W., Washington, DC 20007-5109 (US).

(81) Designated States *(national)*: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CO, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: HYBRID POWER SUPPLY MODULE WITH INTERNAL COMBUSTION ENGINE OR FUEL CELL



(57) Abstract: An hybrid power supply module is disclosed. The hybrid power supply module is configured for placement in a battery compartment of an electrically powered machine and includes a housing that contains a battery, an electrical generator or fuel cell, and control electronics. The housing is sized to fit in the host electrically-powered machine's battery compartment. The battery and electrical power generator or fuel cell are coupled electrically to the electronic controls. A method of replacing a battery in an electric powered machine with a renewable power source is also disclosed. The method includes uncoupling the battery from the machine, removing the battery from a battery compartment of the machine, placing the hybrid power supply module in the battery compartment, and coupling the hybrid power supply module to the machine.

WO 01/079012 A3

TITLE OF THE INVENTION:

HYBRID POWER SUPPLY MODULE WITH INTERNAL COMBUSTION ENGINE OR FUEL CELL

CROSS-REFERENCE TO RELATED APPLICATIONS: U.S. Application number: 09/056,109, filed 04/06/98. This application claims the benefit of priority from U.S. Provisional Application No. 60/197,391 filed April 14, 2000, which is hereby incorporated by reference.

STATEMENT OF GOVERNMENT INTEREST: Not applicable.

BACKGROUND OF THE INVENTION

[0001] The present invention relates generally to power supplies and, more particularly, to a hybrid removable power supply module for a machine such as a forklift, a car, a truck or any motorized vehicle or other machines requiring a power source.

[0002] Powered machinery, and particularly mobile machinery such as motorized vehicles, fork lifts, cars, trucks and vehicles using a regenerableable source of energy are generally designed to operate on either battery (e.g. rechargeable batteries) or fossil fuel power sources (e.g. internal combustion engine, turbine engine or fuel cell). While battery and fossil fuel powered mobile machinery may have quite similar chassis, suspension, lift equipment and hydraulics, the drive portions of the machinery are generally designed specifically for either a battery or fossil fuel power supply. The nature of the drive system design makes electric and fossil fuel machinery fundamentally different and not interchangeable. For example, a forklift design optimized for battery power might include a chassis having an electric motor that powers drive wheels, and an additional electric motor that drives a hydraulic actuation system to power on board auxiliary systems such as lifting, tilting and gripping mechanisms. Whereas, a forklift design optimized for fossil fuel power might incorporate an internal combustion engine that supplies rotary mechanical power to a single hydraulic system from which pressurized fluid is metered through operator controlled valves to hydraulic cylinders and motors which actuate lifting, tilting and gripping mechanisms and also drive the wheels. This optimization of vehicle system designs around the power source makes converting

installed in the vehicle, and directly supplies rotary mechanical power to the vehicle's drive train. The internal combustion engine output is also arranged to recharge the batteries, which are carried in a removable cassette under the vehicle. The battery cassette may be removed and the vehicle operated on power from the internal combustion engine alone.

[0007] U.S. Patent No. 4,320,814 to Middlehoven discloses a removable modular electro-hydraulic power source for mining machinery. This invention purports to provide the ability to rapidly replace the electric motor prime mover, reduction gear set, and hydraulic pumps, thus reducing vehicle down time for maintenance. The removed module is then refurbished in a facility better suited to such work than the mine. The power source for the disclosed system relies on externally provided electrical energy, supplied to the power source via an umbilical from a source remote from the mining machinery.

[0008] U.S. Patent No. 5,419,131 Doppstadt describes a displaceably mounted power unit for use in a mobile waste processing machine. This power unit is captured to the host machine on a hinged mount arranged to provide access to the machine's interior for maintenance and repair.

[0009] Concepts for removable power supplies described above either do not permit a change over from one energy source to another, or require additional structure and mechanisms necessary for both energy sources. Removable power supplies which do not permit switching between electrochemical and fossil fuel energy sources necessarily limit the vehicle applications as discussed above. Vehicles that require structure for both electrochemical and fossil fuel energy sources will necessarily be heavier, more costly and less reliable. Also, energy module designs that require special structural and mechanical interfaces with the vehicle necessarily mean that converting a host vehicle from one type of power source to the other will require expensive, time-consuming and complex modifications. These shortcomings have added to the cost of converting vehicles to hybrid-power sources, thus contributing to the limited commercial successes of hybrid-powered vehicles and hybrid-power conversions of existing vehicles.

[0010] Thus, there is a need for a power supply module that will enable a vehicle to be selectively operated on either battery or fossil fuel power without requiring additional

are permissible, while retaining the ability to function on battery power alone in areas where acoustic, thermal, and gaseous emissions are not desired.

[0015] By being interchangeable with a conventional battery, this invention permits the vehicle to be converted back to all battery power when fossil fuel capabilities are not useful, thus providing the ability to inexpensively increase the machine endurance.

[0016] Another objective of this invention is to provide a means by which a machine such as a forklift can be rapidly reconfigured between conventional battery only and combined battery and fuel cell or internal combustion engine power.

[0017] Yet another objective of this patent is to provide a hybrid power supply module consisting of a fossil fueled internal combustion engine powered generator or a fuel cell generator capable of supplying the average energy needs of an industrial machine, such as a fork lift, mated with a battery which, together with the generator, are capable of satisfying peak power requirements, along with the systems to modulate and control state and rate of charge, peak currents, and over running load power regeneration, all packaged in a volume and weight equal to or less than that of the battery that it replaces.

[0018] Another objective of this invention is to provide an energy module that can enable on-the-fly change over of power supply so that a fork lift or other mobile machine can operate without pollution in a factory wherein workers are employed and revert back to a warehouse using internal combustion provided power without stopping to make physical changes to the vehicle.

[0019] Accordingly, the present invention provides solutions to the shortcomings of prior power sources. Those of ordinary skill in the art will readily appreciate, however, that those and other details, features and advantages will become further apparent as the following detailed description of the preferred embodiments proceeds.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. 1. is a cut away perspective view of the first preferred embodiment of the invention showing components and their general arrangement;

[0027] The hybrid power supply module 15 housing 2 may be fabricated from, for example, metal, plastic, or another suitable material and may be sized to fit into the battery compartment of an electric powered mobile machine such as a fork lift or other mobile equipment. The housing 2 of FIG. 1, may also have a smooth exterior surface and lack protrusions from the exterior surface to simplify installation into and removal from battery compartment. The housing 2 is equipped with first lift point 13 and second lift point 14 to facilitate handling by overhead hoist machinery. Ports for exterior air intake and exhaust discharge 8 may be provided and are depicted on the side of the module in FIG. 1. The air intake and exhaust discharge ports 8 may alternately be located on any side, top, or bottom of the housing 2.

[0028] The fuel cell fuel storage container is depicted as being integral with the fuel cell 3 and thus may be incorporated into the housing 2 as shown in FIG. 1, to form a single, self-contained hybrid power supply module 15 that can be lifted, transported, stored, installed, operated, and removed from the host machine as a single unit. In another embodiment, the fuel storage tank not shown is carried by the host vehicle external to the hybrid power supply module 15. The fuel supply tank, not shown, will have a pipe connection, not shown, to convey fuel to the fuel cell 3, and may have a fill connection, not shown, to replenish fuel, and a means to sense and transmit fuel level to the control electronics 4, not shown.

[0029] The fuel cell 3 may be a common type that oxidizes hydrogen or other fuel and produces an electrical current. The fuel cell 3 will be electrically connected to the control electronics 4. The control electronics 4 will monitor all facets of the hybrid power supply module 15 including the fuel cell's 3 temperature and other operating parameters, fuel supply level, electrical currents, and battery 1 voltage.

[0030] The first preferred embodiment of the invention is presented schematically in FIG. 2. Referring now to FIG. 2, as shown in the schematic, solid lines depict the flow of power whereas dashed lines depict the flow of information. The battery 1, electronic controls 4, and host vehicle 31 power input 7 are electrically connected in parallel on a single buss 16. The control electronics 4 will condition the electrical energy from the fuel cell generator 3 and supply current to the buss 16. The electronic controls 4 are arranged to continuously and

this translates to 48 v- [0.2 v/cell][24 cells] or 43.2 volts for a fully charged battery 26 or 42 v - [0.2 v/cell][24 cells] or 37.2 volts when fully discharged.

[0036] A lead acid battery is recharged by reversing the flow of electric current. Electricity flows from higher potential to a lower one, so for electrical current to flow into the battery its potential must exceed that of the battery 1. Charging potentials for lead acid batteries are typically about 0.3 volts per cell, or so, above the battery's 1 open circuit potential which will result in an electrical current roughly equivalent to 15 percent of the "six hour rate" ampere-hour rating. Greater potentials and currents are not desirable, since these may damage the battery 1. Furthermore, as the battery 1 is charged the current must be reduced so the battery 1 does not overheat.

[0037] When the battery 1 is at a low charge, or current draws by the host vehicle 31 is high, as indicated by a low electrical buss 16 potential, the fuel cell 3 and electronic controls 4 will supply a higher current to the buss 16. When there is little current drawn by the host vehicle 31 and the battery 1 is nearly fully charged, as indicated by a high electrical buss 16 potential, the fuel cell 3 and electronic controls 4 will supply a smaller current to the buss 16. The fuel cell 3 and electronic controls 4 will reduce the current to the battery 1 to a very small value when it reaches a value which corresponds to a fully charged battery 1. In one preferred embodiment of the invention, the fuel cell 3 and electronic controls 4 are arranged to provide maximum current at buss potentials below about 1.75 volts per cell, current in amperes of approximately 15 percent of the battery 1 "six hour rate" ampere-hour rating at buss 16 potentials from 1.75 to 2.1 volts per cell, current of about 4 percent of the battery 1 "six hour rate" ampere-hour rating at buss 16 potentials from 2.1 to 2.7 volts per cell, and current not exceeding 0.5 percent of the battery 1 six hour ampere-hour rating at buss 16 potentials above 2.7 volts per cell. When static or operating at low loads, the electrical current supplied to the buss 16 from the fuel cell 3 via electronic controls 4 serves to maintain the battery 1 in a state of high charge and to prevent damage from overcharging. This translates to the following for the aforementioned illustrative example:

shown) for conveying the measured parameters. In one embodiment, a switch (not shown) is provided on the operator display and interface 10 for the operator to select manual or automatic fuel cell 3 operation. Push buttons (not shown) are provided on the operator display and interface 10 for starting and securing the fuel cell 3 when in the manual mode.

[0040] The hybrid power supply module 15 may have two modes of operation: manual and automatic. In the manual mode, the authority to operate the fuel cell 3 resides with the operator. The operator may, for example, start the fuel cell 3 to replenish the battery 1 charge by depressing the start button (not shown) on the operator display and interface 10. The fuel cell 3 will then start and supply electrical current to the buss 16 via controls 4 without further action by the operator. Depressing the stop button (not shown) will secure the fuel cell 3. The electronic controls 4 may also function to shut-off the fuel cell 3 automatically if the battery 1 becomes 100% charged to prevent damage to the battery 1 from overcharging. The manual mode is generally selected to prevent operation of the fuel cell 3 when operating in areas where waste heat, moisture, and fumes are problematic. The automatic mode is generally used when functioning in areas where the waste heat, moisture, and fumes from the fuel cell 3 are acceptable. In all cases, the electronic controls 4 will inform the operator of the state of charge of the battery 1 and advise when the fuel cell 3 should be operated to replenish the battery 1 when discharged. In the automatic mode, the electronic controls 4 will automatically start, operate, and secure the fuel cell 3 in accordance with predetermined values of sensed parameters including battery charge level and host vehicle energy consumption rate.

[0041] Whether in manual or automatic mode, the function of the fuel cell 3 is overseen by the electronic controls 4 which starts, operates, monitors, and secures the fuel cell 3 without further action by the operator. The electronic controls 4 monitor the fuel cell 3 performance parameters such as temperature, fuel level, and electrical status, and convey visual and audible alerts, cautions, and warnings to the operator via the operator interface and display 10 when values outside a prescribed range are sensed. The fuel cell 3 may be arranged to automatically reduce output or secure if a critical sensed parameter such as temperature reaches a predetermined threshold. In that event, the operator will also be notified via visual and audible alerts of the termination along with the condition that caused the shut-down.

engine. For example, a suitable internal combustion engine would Fischer Panda PMS 04 D, which produces 4 Kilowatts of electrical power using diesel fuel and is contained within an envelope of 21 inch high, 21 inches long, and 15 inches wide including starting, cooling, muffling, and engine control systems. The internal combustion engine 21 will be fitted with ancillary starting, intake air filtration, cooling, lubricating, muffling, and speed governing systems well known to those practiced in the art and not shown in any FIG. All such ancillary equipment and systems are contained within the housing 25. The internal combustion engine 21 will be fitted with sensors not shown which provide an electrical signal which can be correlated to the engine 21 temperature and lubricating oil pressure. These sensed parameters will be transmitted to the electrical controls 24 via electrical cabling not shown.

[0045] The fuel storage tank 23 may be incorporated into the housing 25 as depicted in FIG. 3, to form a single, self-contained hybrid power supply module 20 that can be lifted, transported, stored, installed, operated, and removed from the host machine as a single unit. In another embodiment, the fuel storage tank 23 is carried by the host vehicle external to the hybrid power supply module 20. The fuel supply tank will have a pipe connection not shown to convey fuel to the internal combustion engine 21, a fill connection not shown to replenish fuel, and a means to sense and transmit fuel level to the control electronics 24, also not shown.

[0046] The generator 22 may be a common type that converts mechanical energy, in the form of, for example, a rotating shaft of the internal combustion engine 21, to electrical energy. The generator 22 will be electrically connected to the control electronics 24. The control electronics will monitor all facets of the hybrid power supply module 20 including the internal combustion engine's 21 speed, temperature, and lubricating oil pressure, fuel tank 23 level, electrical currents, and battery 26 voltage / state of charge.

[0047] The second preferred embodiment of the invention is presented schematically in FIG. 4. As shown in the schematic, solid lines depict the flow of power whereas dashed lines depict the flow of information such as commands and sensed parameter feedback. Referring now to FIG. 4, the battery 26 , electronic controls 24, and host vehicle 31 power input 27 are electrically connected in parallel on a single buss 17. The control electronics 24 will rectify and condition the electrical energy from the generator 22 and supply current to the buss 17.

controls 24 will supply a higher current to the buss 17. When there is little current drawn by the host vehicle 31 and the battery 26 is nearly fully charged, as indicated by a high electrical buss 17 potential, the generator 22 and electronic controls 24 will supply a smaller current to the buss 17. The generator 22 and electronic controls 24 will reduce the current to the battery 26 to a very small value when it reaches a value which corresponds to a fully charged battery 26. In one preferred embodiment of the invention, the generator 22 and electronic controls 24 are arranged to provide maximum current at buss potentials below about 1.75 volts per cell, current in amperes of approximately 15 percent of the battery 26 six hour ampere-hour rating at buss 17 potentials from 1.75 to 2.1 volts per cell, current of about 4 percent of the battery 26 six hour ampere-hour rating at buss 17 potentials from 2.1 to 2.7 volts per cell, and current not exceeding 0.5 percent of the battery 26 six hour ampere-hour rating at buss 17 potentials above 2.7 volts per cell. When static or operating at low loads, the electrical current supplied to the buss 17 from the generator 22 and electronic controls 24 serves to maintain the battery 26 in a state of high charge and to prevent damage from overcharging. This translates to the following for the illustrative example:

Buss Potential, Volts	Current Supplied to Buss by Generator and Electronic Controls, Amperes
Below 42	70
42 to 50.4	25
50.4 to 64.8	7
Above 64.9	1

[0052] The electrical power generator 22 may not be capable of supplying the transient peak energy demands of the forklift 31 or other host vehicle. This will manifest itself when more electrical current is drawn from the buss 17 than can be supplied by the generator 22 via the electronic controls 24. In this instance, the excess power required is supplied by the battery 26. This occurs when the host vehicle's 31 electrical current demand exceeds the maximum value of electrical current available from the generator 22 and electronic controls 24. In this case, the current from the generator 22 via the control electronics 24 which normally charges the battery 26 reverses to make up the difference. This reversal occurs automatically and passively. After the transient event has passed, and the host vehicle 31 electrical current

[0055] The manual mode is generally selected to prevent operation of the power internal combustion engine 21 when functioning in areas where noise, heat, and fumes are problematic. The automatic mode is generally used when functioning in areas where the noise, heat, and fumes from the internal combustion engine 21 are acceptable. In all cases, the operator display and interface 28 will inform the operator of the state of charge of the battery 26 and advise when the generator 22 should be operated.

[0056] Whether under manual or automatic control, the function of the generator is overseen by the electronic controls 24 which starts, operates, and monitors, and secures the generator without action by the operator beyond pressing the appropriate button.

[0057] The electronic controls 24 monitor the internal combustion engine 22 performance parameters such as temperature, oil pressure, fuel level, and electrical status, and conveys visual and audible warnings to the operator via the operator interface and display 28 when values outside a prescribed range are sensed. The internal combustion engine 21 and electrical generator 22 are shut down and secured automatically if a critical sensed parameter such as oil pressure or temperature reaches a predetermined threshold. In that event, the operator will also be notified via visual and audible alerts of the termination along with the condition that caused the shut-down.

[0058] Referring now to FIG. 5, the hybrid power supply module 20 is shown being lowered into an electric fork lift 33 battery compartment 34 wherein an access cover 35 of the forklift 33 is opened to receive the hybrid power supply module 20. While the second preferred embodiment of the hybrid power supply module 20 has been used to illustrate the act of installing it in the place of the regular electric fork lift 33 battery not shown. The installation of the first embodiment of the hybrid power supply module will be similar. The hybrid power supply module 20 may be placed in the forklift 33 by some means of an overhead lifting device not shown. It is also shown that the invention may be equipped with lifting fixtures 36 and associated hardware to facilitate handling by an overhead lifting device not shown. The forklift 33 illustrated includes an electrically powered drive train consisting of omni directional wheels 37 that are rotatably attached to the fork lift 33 chassis. A lifting mechanism 38 is also operably affixed to the fork lift 33 which may, for example, include lifting, tilting and gripping mechanisms to facilitate material handling by the fork lift 33. As

CLAIMS

What is claimed is:

1. A removable power source, comprising:

a housing ;

a battery disposed within said housing;

an electrical power generator disposed within said housing; and

a power control module disposed within said housing and coupled to said battery and said electrical power generator and arranged to supply power to a machine from either said battery or said generator.

2. The power source of claim 1, wherein said electrical power generator further comprises:

an internal combustion engine; and

an electrical generator coupled to said internal combustion engine.

3. The power source of claim 1, wherein said electrical power generator further comprises a fuel cell.

4. The power source of claim 1, wherein said housing is sized to fit in a compartment for holding a battery of said machine.

5. The power source of claim 4, wherein said housing is removable from the compartment for holding a battery.

6. The power source of claim 2, wherein said internal combustion engine is a spark ignition engine.

7. The power source of claim 2, wherein said internal combustion engine is a compression ignition engine.

8. The power source of claim 2, wherein said internal combustion engine is a rotary engine.

14. The vehicle disclosed in claim 12 wherein said vehicle is a work platform further comprising a scissor type lifting mechanism coupled to said chassis.

15. The vehicle of claim 12, wherein said housing is removable as a unit.

16. The power source of claim 1, wherein said electrical power generator further comprises:

an external combustion engine; and

an electrical generator coupled to said external combustion engine.

17. The power source of claim 16, wherein said external combustion engine is a gas turbine.

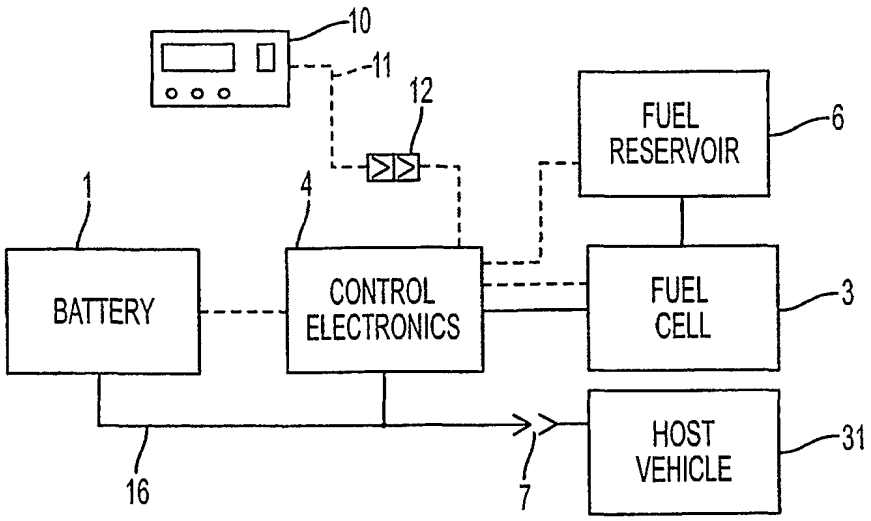


FIG. 2

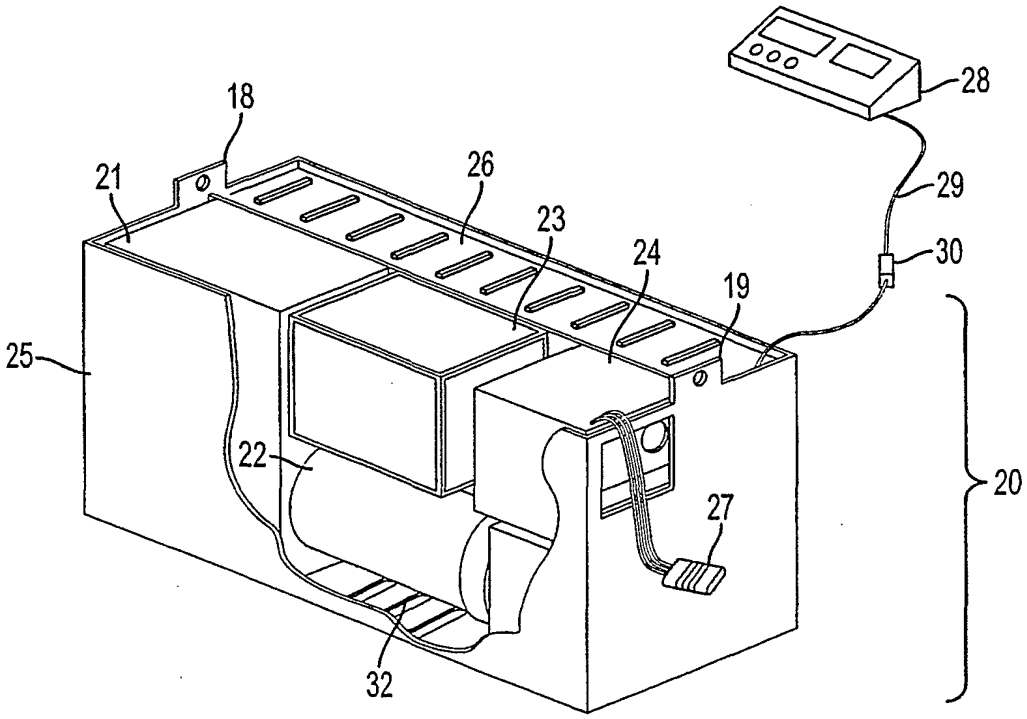


FIG. 3

INTERNATIONAL SEARCH REPORT

national Application No
PCT/US 01/12148

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B60K6/00 B66F9/06 B60K1/04 B60K5/10 B60L11/12
H01M16/00 B60L11/18 B60S5/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B60K B60L H01M B66F B60S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 196 41 254 A (DAIMLER BENZ AG) 16 April 1998 (1998-04-16) * See ref. no. 20 - batteries contained in housing * column 4, line 13 - line 30; figures 3,5 ---	1,2,6, 9-12,15
X	US 4 339 015 A (FOWKES RONALD ET AL) 13 July 1982 (1982-07-13) claims ---	1,2,4-6, 9,12,15
X	US 3 497 027 A (WILD ALBERT F) 24 February 1970 (1970-02-24) column 9, line 52 - line 74; figures 1,2,6 ---	1-3,12, 15-17
X	WO 96 06749 A (EMME QUATTRO SRL ;MORI GIOVANNI (IT)) 7 March 1996 (1996-03-07) claims 1,8,13,14,25 --- -/--	1,2,6,7

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 October 2001	16/10/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Bufacchi, B

Form PCT/ISA/210 (second sheet) (July 1992)

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
DE 19641254	A	16-04-1998	DE	19641254 A1	16-04-1998
US 4339015	A	13-07-1982	BR	7906639 A	26-02-1980
			DE	2963519 D1	07-10-1982
			EP	0003888 A1	05-09-1979
			EP	0009027 A1	19-03-1980
			WO	7900630 A1	06-09-1979
			JP	55500080 T	14-02-1980
US 3497027	A	24-02-1970	NONE		
WO 9606749	A	07-03-1996	IT	BS940094 A1	29-02-1996
			IT	BS940095 A1	29-02-1996
			IT	BS940096 A1	29-02-1996
			IT	BS940097 A1	29-02-1996
			AU	3085695 A	22-03-1996
			WO	9606749 A1	07-03-1996
WO 9902358	A	21-01-1999	DE	19756083 A1	04-02-1999
			WO	9902358 A1	21-01-1999
			EP	0993385 A1	19-04-2000
US 4593786	A	10-06-1986	NONE		
DE 4321768	A	12-01-1995	DE	4321768 A1	12-01-1995
GB 1129709	A	09-10-1968	NONE		
EP 0936178	A	18-08-1999	JP	11222390 A	17-08-1999
			CN	1225333 A	11-08-1999
			EP	0936178 A1	18-08-1999
			US	6189636 B1	20-02-2001